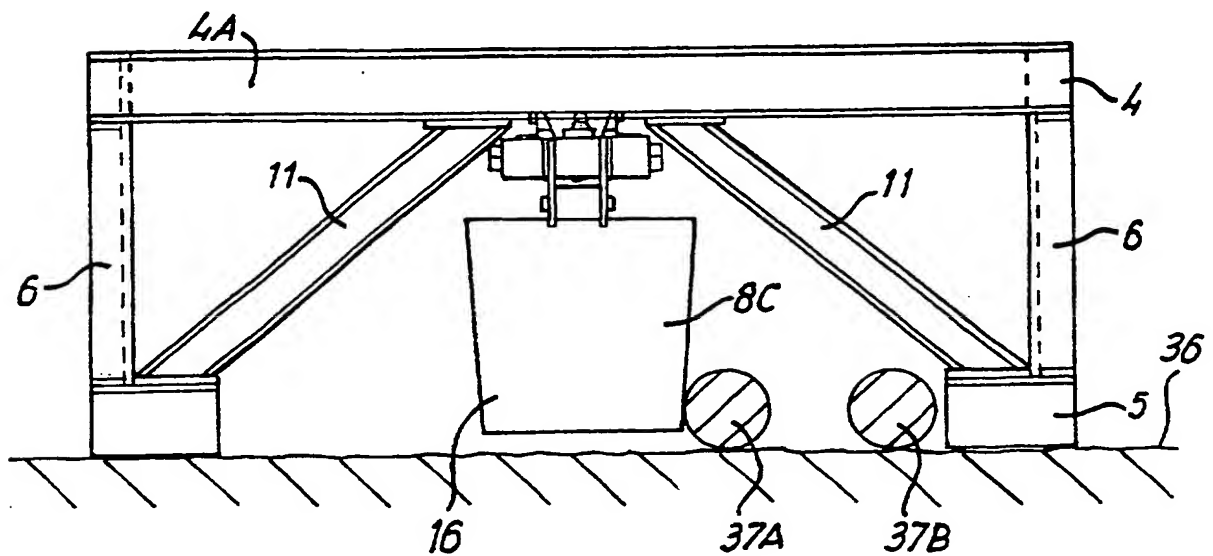
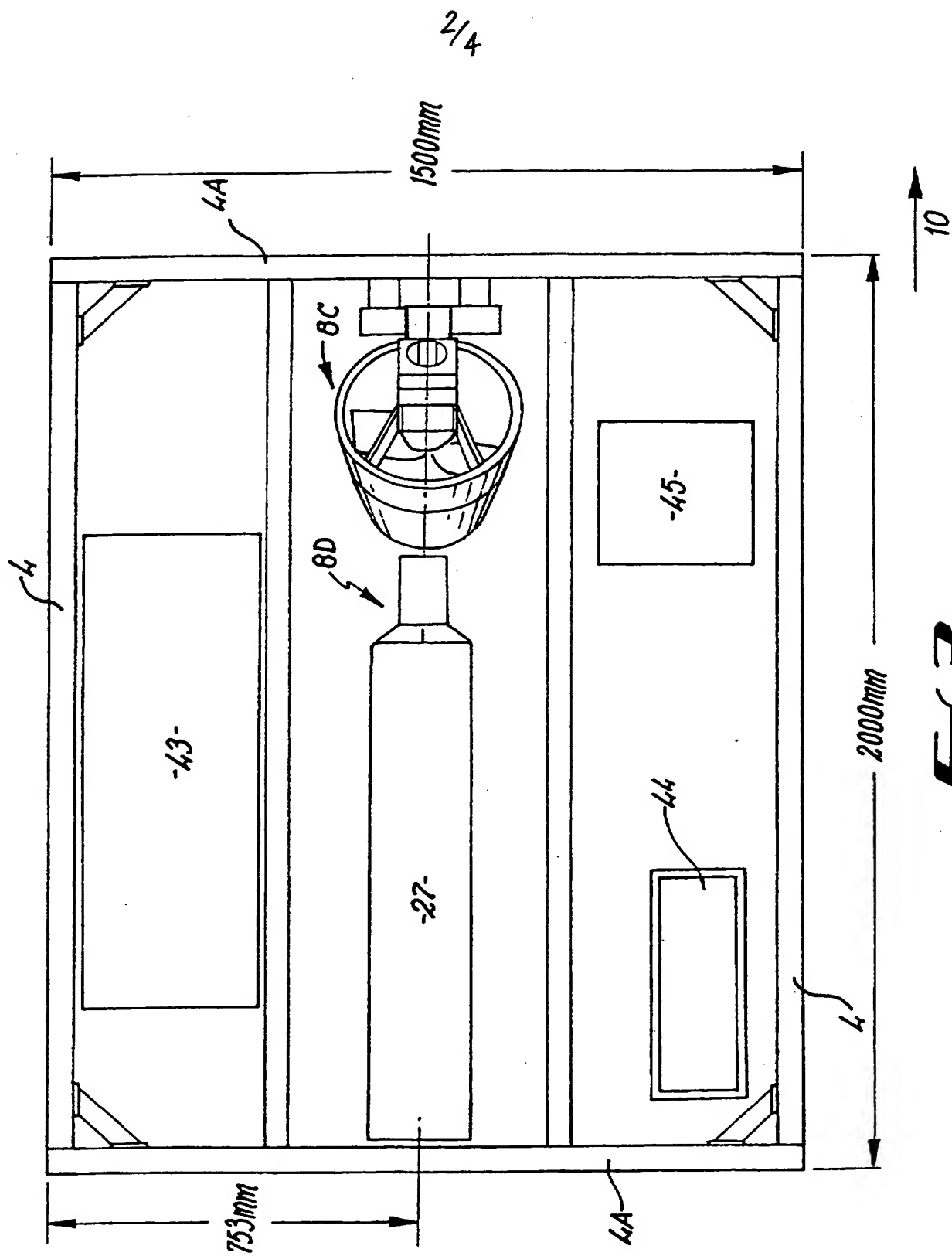


**FIG. 1**

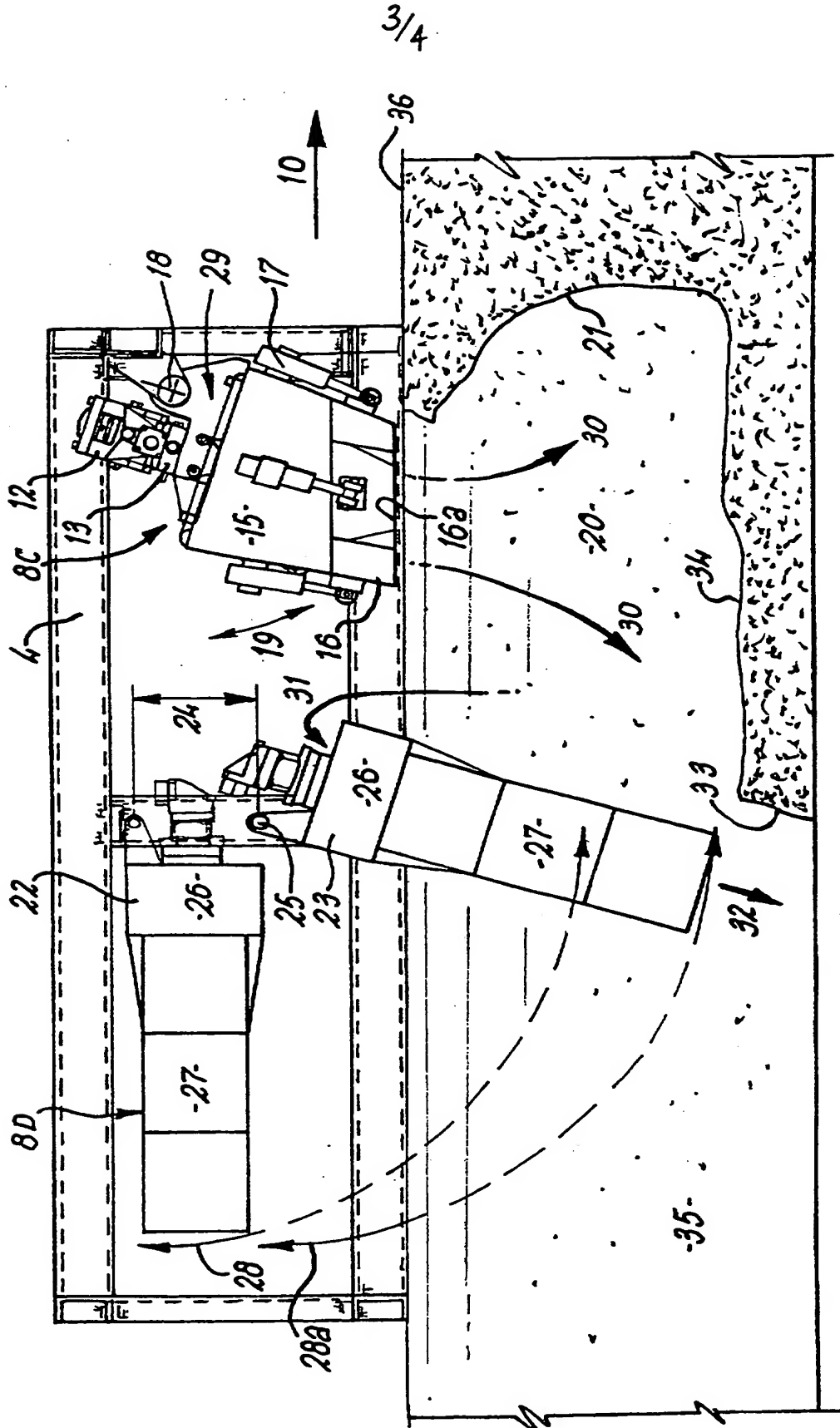


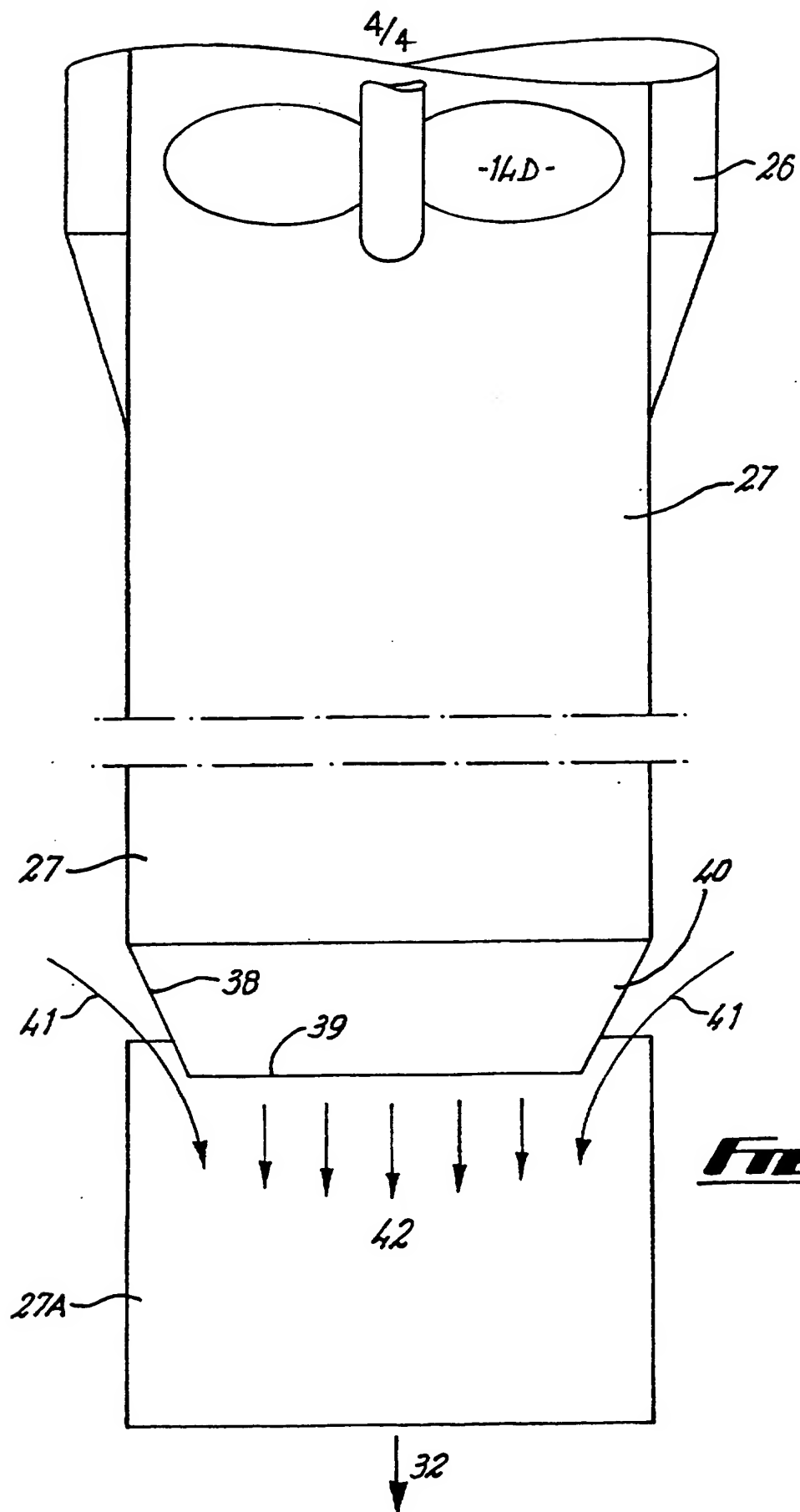
**FIG. 2**



**Fig. 3**

**FIG. 9**





IMPROVEMENTS IN / OR RELATING TO CABLE BURIAL APPARATUS

5 This specification relates to the burial of underwater cables, and the like, in the beds of the sea, lakes or rivers.

When cables are laid in water, it is normal practice to bury them in the seabed / lakebed, etc. so that the risk of damage, e.g. by fishing boats using trawling apparatus, anchors, etc., is minimised. The requirement to bury cables used to be limited to a  
10 relatively short distance offshore and in only shallow seas, but the increasing use of deep water trawling and other offshore activities, such as oil and gas exploration and production, necessitates the burial of deep water cables as well.

The principle of burying cables in water is known and usually takes the form of  
15 excavating a trench with a high velocity water jet. The cable is then allowed to drop into the trench which is backfilled by the natural action of currents in the water over a period of time. Though presently available systems can excavate a shallow trench and bury a cable, it is usually only about 300 - 450 mm below the seabed and underwater currents can frequently expose such shallowly-buried cables with the risk of subsequent  
20 damage.

In view of the dependence of modern society on underwater power and communications cables, it is sensible to provide a deeper burial so that the risks of damage, and the disruption caused by downtime, are minimised. A burial depth of at least 1m is  
25 normally required and, ideally, it should be 1½m.

Many current burial devices use high velocity water jets to excavate trenches. These are generally very inefficient in their use of power, compared to the depth of burial usually achieved. 'High velocity' implies relatively small outlet nozzles and high power  
30 consumption. Underwater, the jet velocity is quickly dissipated by the surrounding water and its cutting effect rapidly diminishes. Near the seabed, are currents moving sediment, seaweed, etc. around and this is accentuated by additional material churned up by the jets themselves. In practice, it is common for such sediments, etc. to be drawn into the water intakes causing clogged filters, damaged impellers and blocked

nozzles. The cost of downtime to return the excavation apparatus to the surface, clean it and resume burial is very high. During this cleaning period, much of the trench already excavated is likely partially to fill in and may have to be re-excavated to bury the cable to the required depth.

5

Many current excavation devices can be operated only from manned submersibles and thus suffer from the limitations of the onboard power supplies. While unmanned submersibles are also used, the power transmission capabilities often limit the size of the excavation pumps.

10

There is thus a need for a more reliable, power-efficient means which can bury a cable sufficiently deeply to avoid all but the most exceptional hazards.

15

According to the invention, there is provided apparatus for burying a cable underwater comprising:-

- i) a first water jet directed at an angle at the bed of the sea / lake / river;
  - ii) a second water jet(s) directed at an angle to the bed and into the hole excavated by the first water jet using a suspension of water and sediment created by the action of the first water jet; and
  - 20 iii) a source of power to operate said first and second water jets;
- characterised in that the apparatus is mounted in a frame, and provided with a means to move along the line of the cable to be buried.

25

According to a first variation of the apparatus of the invention, the second water jet discharges through a duct, the angle of which is adjustable relative to the bed.

According to a second variation of the apparatus of the invention, the means of providing motion is a submersible vehicle.

30

According to a third variation of the apparatus of the invention, the means of providing motion is included within the apparatus.

According to a fourth variation of the apparatus of the invention, the means of providing motion is towing by a cable.

- In one preferred application of the apparatus, each water jet is produced by a
- 5 propeller(s), driven by an electric, or hydraulic, motor via a thrust bearing. The frame is attachable to the underside of a submersible vehicle, e.g. a remotely operated vehicle (ROV). The first water jetting apparatus is mounted at the front of the frame (with respect to the forward motion of the ROV), pointing downwards and backwards (with respect to the forward motion of the ROV). The second water jetting apparatus is
- 10 mounted behind, and in line with, the first water jetting apparatus (with respect to the forward motion of the ROV). Ideally, the second water jetting apparatus is rotatably mounted so that, as the ROV moves forward, the duct, through which its efflux is directed, can be swung downwards in an arc and retracted after use..
- 15 In operation, the ROV would be positioned over the line of the cable to be buried so that the frame, attached to its underside, rested on the seabed and straddled the cable. Both first and second water jets would be started. The action of the first jet, at the front, would start to excavate a hole by washing away particles of sediment and small stones. After a short time, e.g. a quarter to half a minute, the ROV would start to move
- 20 forward along the line of the cable so that the second jet would be over the hole excavated by the first jet and its efflux duct could be swung downwards into the hole. By directing the second jet at the bottom of the hole, the full power of the water flow is concentrated on deepening the hole. As the ROV moves forward continuously, the hole becomes elongated into a trench, into which the cable will fall when a long enough
- 25 length of trench has been excavated.

Ideally, power for both the ROV and the burial apparatus is supplied from a mother ship on the surface.

- 30 In a second preferred application of the invention, a third water jetting apparatus is provided at the rear of the frame pointing longitudinally rearwards (with respect to the forward motion of the ROV) so that its efflux provides forward motion.



In a third preferred application of the invention, the forward motion is provided by a towing cable. This could either be from a ship on the surface or via a shore winch reeling in the cable. In particular situations, the deep water burial could use movement provided via a submersible, or via its own rearward jet. In relatively shallow water, towing behind a ship may be preferred and close to the shore, by a shore-based winch. This combination of means of providing motion allows the trench to be excavated from deep water, through the tidal zone right up onto dry land. For example, using a shore winch at high tide, the apparatus could excavate as far up the beach as possible and, at low tide, a wheeled digger could complete the job.

It should be noted that the first jet draws in essentially clear water from ahead of the ROV and the efflux is mostly rearwards. The second jet is located behind the first one and thus draws in a great deal of the sediment suspension created by the first jet. The sediment, e.g. sand, has a greater density than sea water and thus gives the water jet greater momentum than would be the case with water alone. This, coupled with the abrasive nature of the sediment, creates a much more efficient cutting action, allowing a trench of over 1½m deep to be excavated in most types of seabed. It will be noted that this is in sharp contrast to conventional high velocity jet burial means which are specifically designed not to ingest sediment to minimise the risk of blockage.

The density of sea water is 1025 kg/m<sup>3</sup> and an average value for sand / gravel / shale is about 2000 kg/m<sup>3</sup>. Thus, if the suspension contained, say, 10% sand, etc., the effective density of the second jet would be about 1120 kg/m<sup>3</sup>. This is equivalent to about a 9% increase in mass.

According to a fifth variation of the apparatus of the invention, means are provided to increase the solid content of the water jets.

In a preferred development, apertures are provided in the efflux duct of the second jet to allow dense suspensions of sediment to be drawn into the efflux by venturi effects so that the effective density and abrasion efficiency of the jet is further increased. If the apertures are placed some distance along the duct, they will be in the hole excavated by the first jet at points where the suspension density will be much higher. Thus, by ingesting a proportion of dense slurry into the suspension, the effective density of the whole will be further increased, as will its cutting efficiency.

According to a sixth variation of the apparatus of the invention, means are provided to alter the angle of the duct and efflux from the second jet into, and out of, the hole created by the first water jet.

When not in use, the second jetting apparatus, and its efflux duct, would be swung upwards into the frame but, when in use, means are provided to swing it downwards into the trench. This means could be hydraulic. One advantage of hydraulic means is that could incorporate a 'spring' such that, if the forward motion of the ROV encountered a large rock, the duct could deflect to pass it without damaging the excavating apparatus. Once the rock had been passed, the 'spring' would swing the duct back down to excavate the full depth of the trench.

A typical speed of excavating a 1½+m deep trench could be 250m per hour, or greater, depending on the nature of the seabed. Such a length of trench would remain essentially open for over an hour so that the catenary of the cable would settle it into the bottom. Cables are usually laid with a fair degree of axial tension so that a reasonable length of trench must be opened, and kept open, to allow the relatively flat catenary to enter the trench to the required depth.

30

For a clearer understanding of the invention and to show how it may be carried into effect, reference will now be made, by way of example only, to the accompanying drawings in which:-

Figure 1 is a side elevation of the apparatus of the invention mounted beneath a ROV;

5 Figure 2 is a front elevation of the apparatus of the invention shown in Fig. 1;

Figure 3 is a plan of the apparatus of the invention shown in Fig. 1;

Figure 4 is a sectional side elevation of the apparatus of the invention, showing the cable burial operation in progress; and

Figure 5 is a diagrammatic section of a variation to the design of duct 27

10

In the following description, the same reference numeral is used for identical parts, or different parts fulfilling an identical function.

Referring to Fig. 1, a Remotely Operated Vehicle (ROV) 1 is shown mounted on top of  
15 burial apparatus 2 consisting of a frame structure formed by top members 4, bottom members 5 and side members 6 and containing an excavating means 8C and 8D. ROV 1 is provided with all the usual equipment, including thrusters 8 (8A for moving in the horizontal plane and 8B for moving in the vertical plane) and cameras / sonar equipment, e.g. 9. ROV 1 is connected via an umbilical cable(s) (not shown) to a  
20 mother ship (not shown). Umbilical cable(s) (not shown) provide electrical power, to operate thrusters 8 to control the ROV's movements, e.g. forward motion 10, and all its other systems as well as carrying the photographic / sonar images from camera 9 to the mother ship. A power connection (not shown) is provided between ROV 1 and burial apparatus 2, so that power is available for an unlimited time period. Alternatively,  
25 apparatus 2 may have a direct power link (not shown) to the mother ship.

ROV 1 is built into a metal frame of which the base is member 3. Member 3 sits on top of apparatus 2 and mates with top member 4 of the frame, as shown in Fig. 1. Members 3 and 4 are removably connected so that the movement of ROV 1 controls the  
30 positioning and movement of apparatus 2. Frame 4, 5, 6 is built from high quality aluminium sections and includes a base member(s) 5 with faired leading edges 7.

Frame 4, 5, 6 has the form of an inverted 'U' (Fig. 2) with two sides formed by members 6 and connected by cross members 4A, in the plane of member 4, and strengthened by diagonal bracing 11, etc. but all such strengthening members are clear of the seabed 36. Sides 6 may be extended downwards, if required, to give greater seabed clearance.

5

This makes it possible for ROV 1 to be placed straddling a cable 37 running longitudinally underneath frame 4, 5, 6 and between the two sides 6. Located in frame 4, 5, 6 are two ROV-type thrusters 8C and 8D. Conventional thrusters are preferred as they are 'off the shelf' items and can be purchased readily without having to be designed as separate units. As shown (Figs. 1 and 4), each thruster consists of a motor 12, a  
10 thruster bearing 13, which is pressure compensated for depth, a propeller(s) 14 and a cowl 15 around propeller(s) 14. Thrusters 8 produce a large volumetric flow at a medium velocity and, when directed at the seabed, are very effective excavators.

15 By using off the shelf thrusters, the cost of the apparatus is kept to a minimum and spares are easily obtained. As shown in Fig. 4, cowl 15 on thruster 8C is extended by duct 16 down nearly to lower base member 5. Hydraulics 17 allow duct 16 to be moved up and down relative to the seabed 36 to optimise excavation efficiency as well as to change the shape of nozzle 16A. The end 16A of duct 16 is angled to direct efflux 30 at  
20 seabed 36. When thruster 8C is operated, it draws in essentially clean water 29 from ahead of apparatus 2 and ejects it through duct 16 as a jet of water directed at the seabed 36. The affect of this jet is to wash away the fines and small stones to create a hole 20. As ROV 1 moves itself and apparatus 2 forward 10, hole 20 becomes elongated into a shallow trench.

25

As shown (Fig. 4), the action of the efflux 30 from duct 16 causes undercutting 21. The shape of duct 16, the mass and velocity of efflux 30, seabed clearance and forward speed 10 can all be altered to optimise the rate of excavation and / or trench width according to the nature of the seabed substrate.

30

A second thruster assembly 8D operates in conjunction with first thruster assembly 8C. Here, the thruster assembly 8D has a smaller diameter than that of 8C (Fig. 3) as the purpose is to excavate a deep, narrower trench 35 rather than a wider hole 20. The combination of a wide topped, deep trench minimises risk of the sides slumping and filling the trench before a sufficient length has been excavated to allow cable 37 to enter it to an adequate depth.

As shown, efflux duct 27 is longer than that 16 of assembly 8C. Thruster assembly 8D is provided with means (not shown) to move it from a stowed position 22 to a deployed position 23 about hinge 25. Vertical motion of mounting and hinge 25 is provided 24 and the arcs of movement 28 and 28A are shown about the upper and lower positions respectively. When deployed 23, duct 27 enters hole 20 and excavates a deep trench 35.

Assembly 8D and duct 27 should not be rigidly fixed in the operating position, but be able to move 28A, in case the forward motion 10 of ROV 1 brings duct 27 into contact with a buried rock. Hydraulic devices (not shown) are one means by which assembly 8D and duct 27 can be moved 28 and could incorporate a hydraulic 'spring', or an equivalent means, to permit a reaction to the presence of a buried rock without damaging duct 27. Once the obstruction had been passed, the spring would re-deploy the assembly 8D and duct 27 back to the operating position 23.

A similar device (not shown) could control the movement 19 of thruster assembly 8C about hinge 18. Fig. 3 shows the hydraulics power pack 43 and valve chest 44. The alignment of thruster assemblies 8C and 8D is shown in line with and parallel to the direction of motion 10. A multiplier 45 is provided to give extra features (not shown) to cope with particular problems, e.g. difficult seabed substrates. Such features could be pulsed flows or use high velocity jets of the prior excavation art in short bursts very close to the excavation face, etc.

Because of the forward motion 10 of ROV 1 and the angle of first jetting assembly 8C, the water 31 ingested by propeller(s) 14D of second jetting assembly 8D will contain a suspension of sediment particles. This will make the effective density of the slurry efflux 32 greater than that of clear water so that, for a given velocity, it will have a greater momentum and will thus have a more intensive excavating action than would clear water. There is a further benefit in that the sediment particles are abrasive and so 'scour' the seabed, rather than just 'washing it'. An analogy would be to compare the effect of a cleaning jet of water with that of a sand blaster; the blaster has a much more powerful cleaning effect. Thus, the suspension has a more efficient excavating effect than clear water. The result of this is that a trench 1½ - 2m deep can be excavated in most seabeds at an economic rate.

Such a deep trench will maintain a reasonable depth for a sufficiently long period of time for ROV 1 to move forward 10 and allow the natural catenary of the cable to drop into the bottom of the trench sufficiently deeply to avoid subsequent exposure due to the movement of the sea bed by currents. Fig. 2 shows a section through cable 37 as it passes under frame 4, 5, 6. A cable 37A, adjacent to duct 16, would fall naturally into trench 35 as the burial proceeded. If the cable 37B was alongside base member 5, it might not fall into trench 35 and, periodically, ROV 1 would have to stop excavating and return to push the cable 37B into trench 35. The disadvantage of the 37A position is that the cable could be damaged by rapidly moving debris in the trench caused by efflux 32. Guides (not shown) may be used to move the cable from position 37B to 37A as the excavator 2 moves forward 10. The guides could also push cable 37 down into the trench.

In order to improve the efficiency of excavation, as dense a slurry as possible should be jetted through duct 27 into trench 35. The bulk density of the slurry can be increased by incorporating some of the dense slurry in hole 20 / trench 35 into the efflux 32, as shown in Fig. 5. Here, propeller(s) 14D draws in water and sediment 31 and pumps it out through duct 27. Part of the way down duct 27, the section narrows to form a nozzle 38 with a vena contracta 39. The flow 42 through this nozzle creates a venturi effect, drawing dense slurry 41 into duct 27A through annular aperture 40 and ejecting the mixture 32 as a concentrated, abrasive cutting jet.

Arrows 42 are all of equal length to indicate a high level of turbulent flow in duct 27. Observations have shown that a high degree of turbulent flow makes most efficient use of the abrasive characteristics of the sediment particles.

5

It will be noted that the propellers 14 are large and of open design in cowls 15. ROV thrusters 8 are designed like this as they frequently have to operate in murky waters containing sediment and seaweed. Such debris can pass through propellers 14 without causing damage or obstructing flow. Thus, in use as an excavator, when sediment, stones, seaweed, jetsam, etc. are all likely to be disturbed, blockage is most unlikely, allowing the apparatus 2 to operate on a continuous basis, e.g. 24 hours a day for as long as weather conditions on the surface allow the mother ship (not shown) to maintain station. Similarly, vena contracta 39 and inlets 40 in duct 27 are large and unlikely to become obstructed. Inlets for flows 29 and 31 are well above the adjacent seabed so that ingestion of stones is unlikely but seaweed, etc. could be drawn in. In the event of a blockage, simple reversal of the direction of propeller(s) 14C, 14D should release the obstruction. Backflushing is not normally possible with high velocity nozzles of the prior art as the obstruction usually remains in the system and causes a re-blockage.

20

The efficiency of the invention thus relies on the combination of:-

- i) a plurality of excavation jets operating in series;
- ii) the use of an abrasive and denser medium in the second (and subsequent) jet(s);
- 25 iii) high volumetric flow rates at a relatively low velocity;
- iv) the use of an open propeller in a large duct to minimise risk of blockage; and
- v) highly efficient use of power.

One unique feature is the use of specially designed propeller(s) 14 to create cavitation. This is where a low pressure is generated by the shape of the propeller blade and causes dissolved air in the water to form bubbles. As the bubbles return to normal pressure, they implode, collapsing with explosive violence. The effect of such cavitation  
5 provides a further level of efficiency to the excavation process and is especially useful in hard resilient seabeds, such as boulder clay.

Tests have shown that the apparatus of the invention, with the design and configuration shown in the Figures, can excavate an equivalent size hole / trench with less than 25%  
10 of the power consumption than would be used by currently available high velocity burial equipment.

The description above refers to the excavation apparatus 2 secured beneath a ROV 1. This is only one configuration. In another (not shown), a third thruster 8E could be  
15 provided behind 8D, e.g. as shown for 8D in position 22. This third thruster 8E would provide the forward drive effort to move the apparatus 2 forward 10. Thruster 8E would have vectored thrust to guide apparatus 2 on to cable 37 and in the required direction along it. Clearly, umbilical control and power cables (not shown) would be required, as would camera / sonar guidance and possibly buoyancy facilities. This  
20 option would allow cable burial in the absence of a ROV.

A third means of movement is via a cable from a shore winch. This would be particularly useful in tidal reaches where a mother ship could not operate. Provided water inlets 29 and 31 were covered, apparatus 2 could operate in very shallow water,  
25 e.g. only 300-450mm deep. Clearly in this configuration, the control and power umbilicals would also come from the shore and be winched in as the apparatus moved forward.

30

IP519



What we claim is:

- 1      Apparatus for burying a cable underwater comprising:-
  - i)      a first water jet directed at an angle at the bed of the sea / lake / river;
  - 5      ii)    a second water jet(s) directed at an angle to the bed and into the hole excavated by the first water jet using a suspension of water and sediment created by the action of the first water jet; and
  - iii)    a source of power to operate said first and second water jets;characterised in that the apparatus is mounted in a frame, and provided with a means to  
10    move along the line of the cable to be buried.
- 2      Apparatus for burying a cable underwater as claimed in claim 1, wherein the water jets are produced by adaptations of the means used to propel a submersible vehicle.  
15
- 3      Apparatus for burying a cable underwater as claimed in claim 2, wherein further water jet(s) are used in series with the first and second jets.
- 4      Apparatus for burying a cable underwater as claimed in claim 3, wherein at least  
20    one of the jets discharges through a duct.
- 5      Apparatus for burying a cable underwater as claimed in claim 4, wherein the angle of the duct relative to the seabed is adjustable.
- 25    6      Apparatus for burying a cable underwater as claimed in claim 5, wherein the angle of the duct relative to the seabed can be varied to and from a preset value to accommodate obstructions along the line of the cable to be buried.
- 7      Apparatus for burying a cable underwater as claimed in any preceding claim,  
30    wherein the source of power to operate the apparatus is supplied from an external source.

8       Apparatus for burying a cable underwater as claimed in claim 7, wherein the means to move the apparatus along the line of the cable to be buried is attached to the apparatus.

5       9       Apparatus for burying a cable underwater as claimed in claim 8, wherein the means to move the apparatus along the line of the cable to be buried is a further water jet.

10       10       Apparatus for burying a cable underwater as claimed in claim 7, wherein the means to move the apparatus along the line of the cable to be buried is provided by a submersible attached to the apparatus.

15       11       Apparatus for burying a cable underwater as claimed in claim 7, wherein the means to move the apparatus along the line of the cable to be buried is a towing cable attached to the apparatus.

20       12       Apparatus for burying a cable underwater as claimed in any preceding claim, wherein means are provided to increase the solid content in the efflux from at least one of the water jets.

25       13       Apparatus for burying a cable underwater as claimed in claim 12, wherein the means to increase the solid content in the efflux from the water jet(s) are included in the structure of the duct(s).

30       14       Apparatus for burying a cable underwater as claimed in any preceding claim, wherein the propellers creating the water jets cause cavitation in the efflux.

      15       Apparatus for burying a cable underwater, as claimed in any preceding claim, wherein means are provided to direct the cable either laterally and / or downwards into the trench created by the use of the apparatus.

16 A method of burying a cable underwater comprising the steps of;  
i) providing a first water jet directed at an angle at the bed of the sea / lake  
/ river;  
ii) providing a second water jet(s) directed at an angle to the bed and into  
5 the hole excavated by the first water jet using a suspension of water and  
sediment created by the action of the first water jet; and  
iii) providing a source of power to operate said first and second water jets;  
characterised in that the apparatus is mounted in a frame, and provided with a means to  
move along the line of the cable to be buried.

10

17 A method of burying a cable underwater, as claimed in claim 16, using a  
plurality of water jets sequentially directed at the bed of the sea / lake / river and  
moving progressively forward to excavate a trench and introducing the cable into the  
open trench.

15

18 A method of burying a cable underwater, as claimed in claim 17, using a  
suspension of particulate matter in the water jets.

19 A method of burying a cable underwater, as claimed in claim 17, wherein the  
20 propellers creating the water flow to form the jets cause cavitation to occur in the  
efflux.

20 Apparatus and method of burying a cable underwater as described in the above  
statement with reference to the attached drawings.

25



Application No: GB 0031005.2  
Claims searched: All

Examiner: Philip Osman  
Date of search: 24 May 2001

## Patents Act 1977 Search Report under Section 17

### Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S): E1F (FWDMD), (FWD MX), (FWGE)

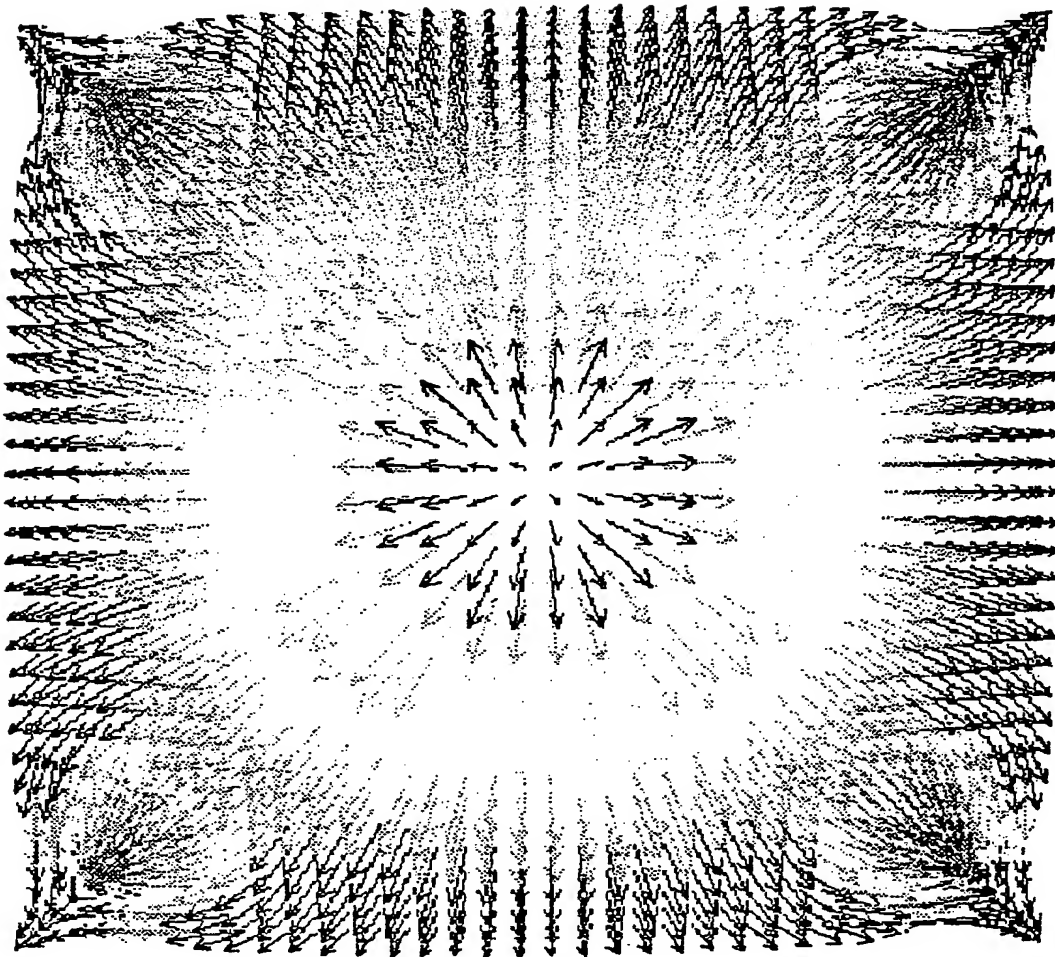
Int Cl (Ed.7): E02F, F16L, H02G

Other: Online: WPI, EPODOC, PAJ

### Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	GB 2,297,777 (Hollandsche Beton Groep)	
A	GB 2,289,912 (Sills)	
A	GB 2,015,618 (Land & Marine Engineering)	
A	GB 1,379,942 (Hydronautics)	
A	US 4,165,571 (Chang, Remkes)	

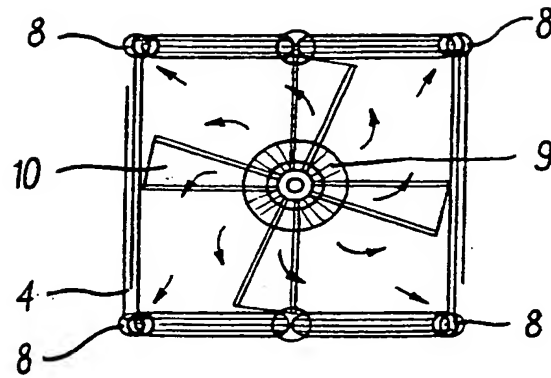
X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.



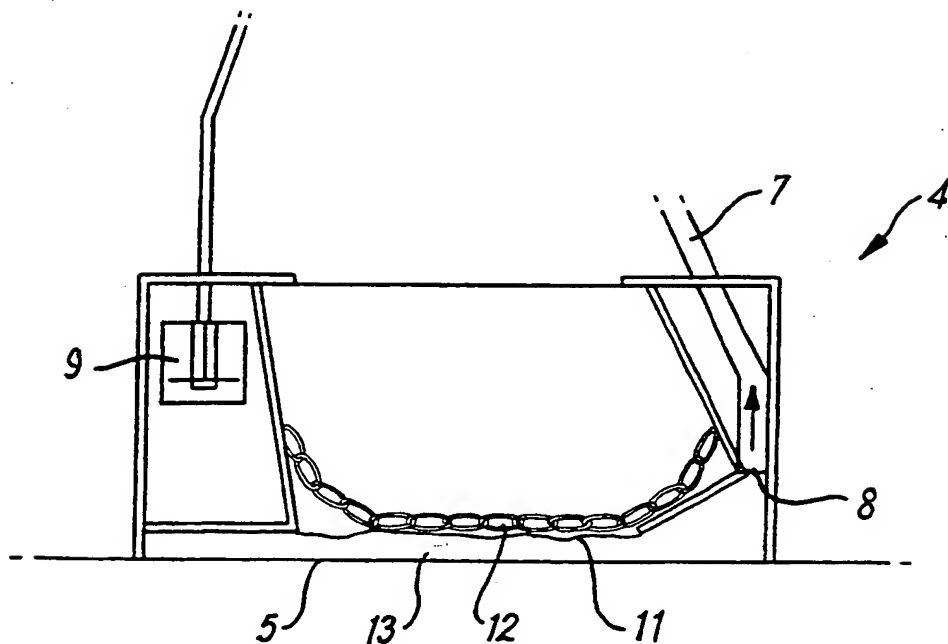
**FIG. 4**

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**FIG. 5**



**FIG. 6**

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